although the visibility in every other direction was good. At 7:30 a. m. smoke sheets in pronounced billow formation began moving toward the station with good velocities. This phenomenon was unusual on account of the great amplitude and wave lengths of the billows, which passed only a short distance overhead, but a little frayed and torn, suggesting the appearance of a large blanket being whipped by the wind. As indicated by the wind-aloft-data from this observation there appeared a stratification of air currents near the surface which probably accounted for the billow formation. Further in this connection attention is invited to the great difference in temperature observed in San Antonio, where there was the protective covering of fog and smoke, and at Kelly Field, 5 miles to the southwest, where free radiation was possible. The temperature in San Antonio at 7 a. m. was 40° F., while at Kelly Field it was 29° F

Attention is called to the surface and free-air wind conditions attending the cold wave that overspread the northeastern part of the country on January 31.

BLIZZARDS AND CHINOOKS OF THE NORTH DAKOTA PLAINS.

By F. J. BAVENDICK, Observer.

[Aerological Station, Ellendale, N. Dak., Mar. 16, 1920.]

Note on the meaning of "Blizzard."—So far as known, this term was first used in the middle western United States to describe a type of winter storm of rather frequent occurrence in that region, characterized by (1) high wind, (2) very low temperature, and (3) an abundance of fine snow in the air. The etymology of the word is still speculative. A plausible hypothesis traces its origin to the German word *blitzartig* ("lightninglike), said to have been applied to these storms by early German settlers in Dakota.

There is a tendency, both in the United States and in other English-speaking countries, to apply the word "blizzard" indiscriminately to any heavy snowstorm accompanied by more or less wind. Some remarks pertinent to this subject, by Bostwick, Dines, and Bonacina will be found in Nature, volume 97, 1916, pages 261, 280, and 301. This broad use of the term impairs its utility for purposes of exact description, and should be discouraged.

It is doubtful whether true blizzards, characterized by intense cold, high wind, and blinding clouds of dry, powdery "snowdrift," ever occur in the British Isles, and they are exceedingly rare in the eastern United States. They are not, however, peculiar to the interior of the American Continent, for the most intense storms of this character heretofore recorded are those of Adelie Land, Antarctica, so graphically described in Sir Douglas Mawson's "Home of the Blizzard" (London, 1915).—*C. F. Talman.*

Picture to yourself a strong gale, snowstorm, and cold wave combined and you have the state of the weather in a blizzard on the open prairie. The most favorable time for one is after a snowstorm, when the temperature is low and the snow has not packed. The blizzard generally begins early in the morning and ends about sunset, although some of the more severe last for three or four days. The whole atmosphere becomes filled with needlelike snow and ice crystals, which, driven by a cold wind of gale force, sting the flesh and sift through the finest crevices. Caught in such a blast one runs the risk of suffocation, the action of the lungs being stopped by the swiftness as well as the intense cold of the wind, while the ice dust, which penetrates the thickest clothing, is more choking than a summer dust storm.

It seems surprising to people unaccustomed to North Dakota weather how easily one may get lost, but should they stop to consider that at times it is impossible to see more than 10 feet away and there is such a roaring and commotion that the human voice can scarcely make itself heard, they would know that one may lose all sense of direction. Experience shows that a person almost invariably walks to the right of the course supposedly being taken, and as a result wanders about in a circle. As a safeguard against this danger some farmers stretch wires from their houses to outbuildings.

Some cattle roam at will and thrive on the grasses without any care or shelter; but during a blizzard they wander aimlessly here and there, sometimes being buried under drifted snow or, in vain attempts to find food and shelter, more frequently traveling with the wind, for no animal will face the storm.

The storm is much more severe on the open prairie than in town because the buildings offer resistance to the wind. The buildings, trees, and cultivation of the soil have also probably locally decreased the severity of blizzards, though, of course, not generally, as compared with former years. The logic of this statement may be more clearly understood after reading the next paragraph which shows that blizzards are comparatively "shallow."

An area of low pressure passes south or east of the station during a blizzard and the wind aloft is usually much lighter than near the ground. The surface wind is from a northerly direction, while aloft it veers toward the easterly, often becoming too light to support the kites. If the kites do not go too far to the west and if they rise through the light air, it is found that the wind backs to a northwesterly direction.

There is much more static electricity in the air during a blizzard than at other times, due, presumably, to the rubbing of snow crystals on each other. There are records of over 10,000 volts on a few hundred meters of wire (see kite flights of Nov. 10, 1919, and Mar. 3, 1920), while on ordinary days the recorded amounts are less than 100 volts for the same amount of wire out. There is usually a slight rise in temperature with altitude sometimes extending to a mile above the surface. The relative humidity is high on the surface and aloft. The one-day blizzards, which were the only kind observed at Ellendale during the past three winters, extend to an altitude of very little over a thousand feet. Above this level weather conditions are about normal. Late in the afternoon the sky usually clears off entirely, while the snow still blows until shortly after sunset. Halos and parhelia, caused by the ice crystals in the air, are often seen before sunset.

After a blizzard, even when the temperature drops to about 40° below zero, it does not feel so cold as during the storm because we are, by this time, near the center of the HIGH, which is accompanied by light wind and low humidity. In the blizzard the temperature drops all day, while on these extremely cold, calm days the temperature is very low at sunrise and rises rapidly during the day. If the wind is strong enough to raise the kites it is found that the temperature does not fall at the usual rate but is about the same at all levels to as high as it is possible to go with the kites.

The weather is not always so cold during the winter or it would be impossible to raise live stock. Sometimes the temperature changes almost 100° F. in a few days, as on February 21 to 23, 1918. This is caused mainly by the effect of the chinook winds. The approach of the chinook is marked by a falling barometer, the winds are light, the sky is cloudless, and the air clear and cold. Objects stand out in bold relief against an intensely blue sky. On some mornings it is possible to see objects which in reality are below the horizon. This is a condition known as looming. The surface wind is always light and generally from the south while, when it is possible to get up with the kites, it is found that the wind is strong and from the west less than a thousand feet above the ground. There is always a big inversion of temperature often amounting to about 30° F. about 500 feet up. This warm air floating above the cold, almost calm surface air causes the inverted image to appear above objects near the horizon. This effect is related to the chinook from the Rockies. The high temperature aloft may come down, but more often there is a big temperature inversion for a few days and then the warm stratum of air disappears.

Sometimes during such pressure distribution, i. e., a HIGH near Utah and a LOW north of Montana or the Dakotas, the effect of the chinook is felt near the ground. The wind is from the southwest to northwest on the surface and aloft it is directly west. Instead of being strong on the surface and light aloft, as in the blizzard, it is light on the surface and very strong aloft. The temperature at this time is much higher above the ground than at the surface and continues so during the entire period of the warm wave, as shown by kite flights in series of November 17 and December 3–4, 1919. The surface wind increases in strength and warmth during the day, but the wind is not so dry and warm as when it crosses the regions nearer the mountain slope, because it has been absorbing moisture and losing heat for a great distance. Nevertheless it is still very warm and dry and fairly eats the snow.

WEATHER FORECASTING.

By H. H. CLAYTON, Chief Forecaster.

[Argentine Meteorological Office, Buenos Aires, Argentina, Feb. 3, 1920.]

The very interesting discussion of weather forecasting by Prof. V. Bjerknes in the MONTHLY WEATHER REVIEW of February, 1919, leads me to recount how a somewhat crude conception of his methods arose in the United States Weather Service, and to suggest how certain relations of the wind to the gradient may be utilized.

In 1892, when acting as local forecaster of the Boston section, I was called into Washington with other local forecasters for the study of the methods in use in the Central Office. There I encountered Mr. Bassler, of Cincinnati, and Mr. Wappenhans, of Indianapolis. In the course of our various discussions Mr. Wappenhans pointed out his use of a line drawn through a low area separating the winds having a northerly component from those having a southerly component of motion. He said it was useful in predicting rain, changes of temperature, and changes of wind. I began drawing these lines and soon convinced myself of their usefulness in predicting weather changes a short time in advance and hence especially useful to a local forecaster. Mr. Wappenhans offered no reason for the observed relations, but I concluded that the rains observed along the line indicated were due to the underrunning of the warm southerly by the cold northerly winds, whereby the southerly winds were chilled by expansion and their moisture condensed. If this was so, I reasoned that besides the line running nearly north and south, which Mr. Wappenhans drew, there might be another nearly east and west separating the cold winds on the northeast side of the cyclone from those on the southeast side. These two lines run nearly at right angles to each other, as is illustrated by the dotted lines in figure 1. In making local forecasts at Boston I frequently drew these lines, either actually or mentally, and I soon found that they were both lines of converging winds. I came to consider the convergence of the winds as the main factor to be considered as the cause of rain and associated fair weather with diverging or parallel winds. It seemed to me that this view was confirmed by tropical cyclones around which there were no great difference in temperature, yet the converging winds produced ample rainfall.

Later, as meteorologist of the Blue Hill Observatory, I became associated with Mr. John P. Fox, who volunteered to assist in certain lines of research. Among those we took up the question of converging winds. The evidence showed clearly that rainfall was intimately associated with converging winds, and Mr. Fox discovered that the quantity of rainfall was related to the steepness of the gradient. In other words, the more rapid the converging winds the greater the rainfall. It was evident also that humidity was a factor, because with equal convergence the rainfall was greater near the coast than over the interior. This work was done between the years 1898 and 1903, but never published, because it was considered incomplete and was laid aside owing to the pressure of other work with the intention of taking it up and completing it later. In 1912 the idea was presented to the officials of the Weather Bureau at Boston and at Washington with examples taken from current weather maps. In 1916, with slight modifications, the essay thus prepared was offered for publication in the WEATHER REVIEW and appeared in the MONTHLY WEATHER REVIEW of February, 1916.

At that time I had not seen the masterly studies of Prof. Bjerknes and Mr. Sandström, who deserve all the credit of originating the theory and putting it on a sound scientific basis; also for first publication. That the facts underlying the theory had been partly outlined by others is a testimony to the truth.

I have not yet seen all of the published results of these able workers, but their researches printed in the MONTHLY WEATHER REVIEW contain no mention of certain phases of the question which I believe can be used by forecasters in anticipation of the numerous observations and the drawing of stream lines as advocated by Prof. Bjerknes. Owing to the great irregularities of local winds it is difficult to draw correct stream lines from a scattered network of stations, but it is possible to draw fairly correct barometric lines, hence I am accustomed to draw stream lines from the observed gradients, using observed winds simply as guides to the inclination of stream lines to the gradients. In the average for land stations in temperate latitudes the wind has an inclination of about 45°. Drawing winds at this angle to the isobars, but making the inclination somewhat less where the isobars are crowded, we get a system of stream lines like that developed in figure 1. The drawing of the stream lines as applied to an actual case in the Northern Hemisphere is shown in figure 2. (See dotted lines.)

Where there are no well-developed HIGHS and LOWS, but the isobars have a wavy form, as illustrated in figure 3, the relations may be embodied in the general statement that isobars concave to the gradient induce converging winds resulting in ascending currents, cloudiness, and rain, while convex isobars induce divergent currents with descent of air and fine weather.

In figure 3, L indicates the direction in which the pressure is low and H the direction of high. L' shows the